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STATE OF SOUTH DAKOTA

Harlan J. Bushfield, Governor

STATE GEOLOGICAL SURVEY

E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

No. 45

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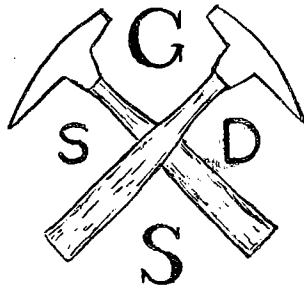
THE MEDICINE BUTTE ANTICLINE

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by

Bruno C. Petsch



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University of South Dakota  
Vermillion, S. Dak.  
December, 1942

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STATE GEOLOGICAL SURVEY

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## APPENDIX

	Page
U. S. Government Rapid City Airport #2.....	i
Gypsy Oil Company Hunter #1.....	iv
U. S. Government Manganese Plant #1.....	vi
Carter Oil Company Stratigraphic Well #1.....	vii
Carter Oil Company Stratigraphic Well #2.....	ix
U. S. Government Pierre Airport #1.....	xi

## LIST OF ILLUSTRATIONS

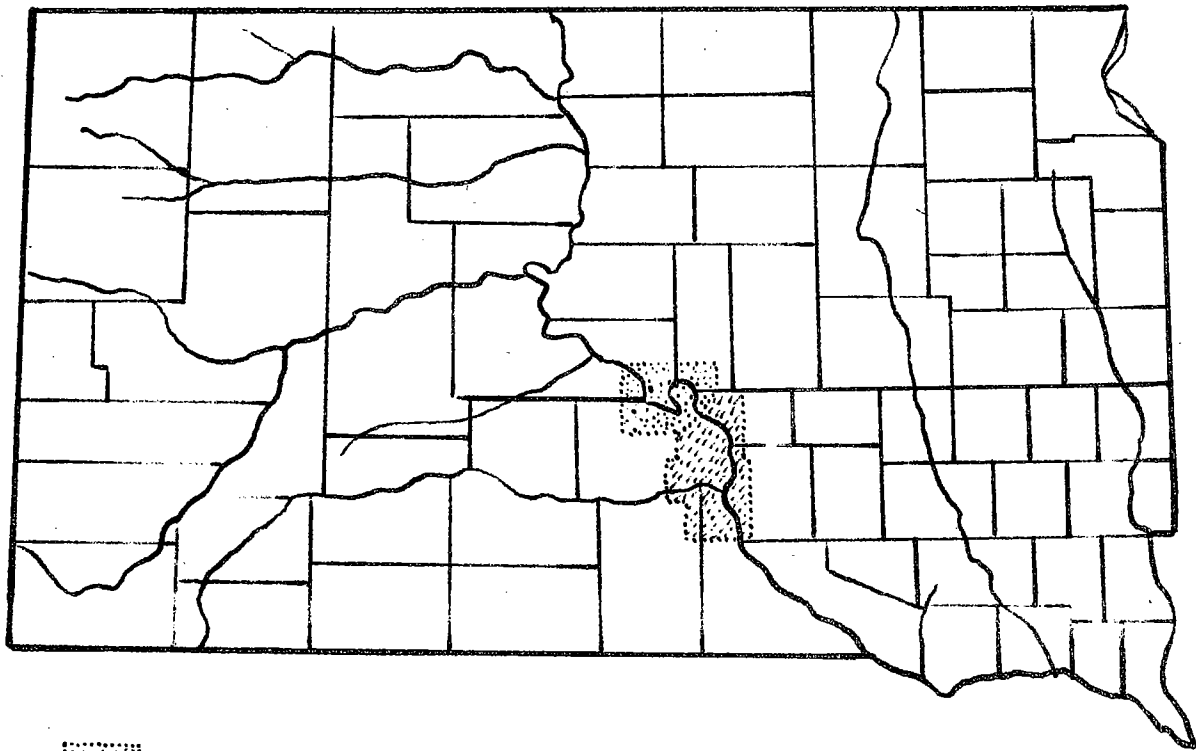
	<u>Figures</u>	Opposite Page
Figure 1	General Columnar Section.....	4
Figure 2	Geologic Map of South Dakota.....	6
Figure 3	Moosejaw Synclinorium.....	12
Figure 4	Structure Map of South Dakota.....	14
Figure 5	Cross-section of South Dakota.....	16
Figure 6	Well Log Correlation Chart.....	18
Figure 7	Magnetic Map of the Medicine Butte Anticline	20
	<u>Map</u>	Back of Report
	Structure Map of the Medicine Butte Anticline.....	


## TABLE OF CONTENTS


	Page
INTRODUCTION	
Methods of Procedure.....	2
Acknowledgments.....	2
STRATIGRAPHY	
I. Formations Exposed at the Surface.....	3
The Niobrara Formation.....	3
The Pierre Formation.....	3
The Sharon Springs Member.....	3
The Gregory Member.....	4
The Sully Member.....	4
The Crow Creek Zone.....	4
The Agency-Oacoma Zone.....	5
The Verendrye Zone.....	5
The Virgin Creek Member.....	6
The Mobridge Member.....	6
Tertiary Deposits.....	6
Key Beds.....	7
II. The Subsurface Formations.....	10
Introduction.....	10
Stratigraphy.....	10
IDENTIFICATIONS OF SOUTH DAKOTA FORMATIONS IN DRILL CUTTINGS	
The Niobrara Formation.....	13
The Greenhorn Formation.....	13
The Dakota-Lakota Group.....	14
The Morrison Formation.....	15
The Spearfish Formation.....	15
The Minnekahta Formation.....	15
The Pahasapa Formation.....	15
STRUCTURE	
Regional.....	16
Local.....	16
GEOPHYSICAL SURVEYS	
OIL AND GAS POSSIBILITIES OF THE MEDICINE BUTTE ANTICLINE	
Mechanics of Oil Accumulation.....	20
Possible Oil Bearing Horizons.....	21
Physiography.....	22
GEOGRAPHIC FACTORS	
Water.....	23

THE MEDICINE BUTTE ANTICLINE

INDEX MAP



 Area covered by this report.

 Area covered in 1940.

# THE MEDICINE BUTTE ANTICLINE

by

Bruno C. Petsch

## INTRODUCTION

In the course of an investigation of the large manganese deposit near Chamberlain, South Dakota, carried on by the State Geological Survey in 1940, the flank of a large geologic structure was discovered.<sup>1</sup> Because of its potential value as an oil prospecting area, the Survey sent a party into the region in 1942 to complete the mapping of the structure.

This structure, which will here be called the Medicine Butte Anticline, is a long arch lying in the eastern part of Lyman County and trending roughly northwest by southeast between the Big Bend of the Missouri River in Lyman County and the Bijou Hills to the southeast in Brule County. Its total length is about 35 miles, and its width about 8 miles and it covers an area of some 280 square miles.

The axis of the anticline passes just east of Medicine Butte which is the most prominent topographic feature in the area. The Butte is an outlier of Quarternary rocks covered by a veneer of glacial drift, located in quarter of T. 106 N., R. 73 W., and covering about four sections of land.

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1. The 1940 field work was done by a party consisting of Dr. E. P. Rothrock, State Geologist; Dr. M. E. Wing and Dr. J. P. Gries, Geologists; Mr. H. E. Brookman, Engineer; Messrs. Ray Maloney, D. P. Rothrock and Richard Aroner, Instrument Men. This work has been described in an earlier report--Stratigraphy and Structure of the Chamberlain Section of the Missouri River Valley. M. E. Wing and J. P. Gries, April, 1941.

## Methods of Procedure

The survey was the same type as that made in the oil fields, where an indication of the structure of oil producing beds some distance beneath the surface is obtained from a determination of the structure of beds at the surface. Numerous elevations were obtained on a key bed by means of the plane-table and telescopic alidade. These were plotted on a base map and structural contours drawn. Sea level elevations were used on the accompanying map. All traverses were run from precise level bench marks, established by the Missouri River Commission, the United States Coast and Geodetic Survey, and the United States Geological Survey.

The 1942 party established headquarters at Kennebec, South Dakota and later at Chamberlain. It consisted of Dr. E. P. Rothrock, and Mr. Bruno Petsch, geologists; Mr. D. F. Rothrock and Mr. Robert E. Wyant, engineers; and Mr. Ray Barron, field assistant.

The area mapped by this party included that portion of the Missouri River known as the Big Bend and extended from Fort Thompson to DeGrey. It also covered the Valleys of Medicine Creek and Cedar Creek which are tributaries to the Missouri River.

## Acknowledgments

The writer wishes to acknowledge his indebtedness to his associates on this survey and to members of former surveys whose assistance was necessary to bring this report to a successful conclusion.

## STRATIGRAPHY

### I. FORMATIONS EXPOSED AT THE SURFACE

The formations exposed along the Missouri River and its tributaries in the area under consideration range from the Niobrara chalk of the Upper Cretaceous age to the glacial drift of Pleistocene age, Figure 1. The formations in this part of the section are the Niobrara chalk, the Pierre shale with its subdivisions, Tertiary clays and sandstones, and Pleistocene glacial clay and boulders. Figure 2 shows the distribution of the surface formations in the area covered by this report with respect to those of the entire state.

#### The Niobrara Formation

The Niobrara formation is an impure chalk. Its color is gray to black when fresh, but in the outcrop, it weathers to a yellowish appearance. The formation contains numerous thin bentonite beds. It is about 200 feet thick but only the upper one hundred feet are exposed along the bluffs of the Missouri River at Chamberlain. Northward, at Fort Thompson, it dips beneath the river level.

#### The Pierre Formation

The Pierre formation consists of a thick series of gray shales with numerous bentonite beds, marl and concretions. These shales overlie the Niobrara Chalk with apparent conformity. The Pierre shale formation is about 1000 feet thick and has been subdivided into six members or divisions by the State Geological Survey.<sup>1</sup>

#### The Sharon Springs Member

The Sharon Springs member lies at the base of the Pierre formation. Its lower part is a dark bituminous shale con-

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1. Gries, J. P., Economic Possibilities of the Pierre Shale, S. Dak. State Geological Survey Report of Investigations No. 43, May, 1942.



taining an abundance of fish scales; its upper part is a soft bluish-gray shale, characterized by occasional specks of red hematite, and the absence of fish remains and concretions. This member is from 9 to 34 feet thick.

#### The Gregory Member

The Gregory member is divided into two zones. The lower zone is an impure light gray chalk about 8 feet thick, a thin layer of buff limestone or large limestone concretions are sometimes present at the base and overlain by a very calcareous shale. The upper zone is a tan colored, light buff to gray shale. Alternate beds of dark noncalcareous shale and light calcareous shale give it a banded appearance. Brown ironstone concretions, some carrying a conspicuous molluscan fauna are fairly abundant. The member is about 38 feet thick.

#### The Sully Member

This member of the Pierre formation is exposed continuously along the Missouri and the parts of its tributaries from northern Nebraska as far north as Mobridge, Walworth County, South Dakota, where the uppermost zone passes beneath the level of the River. It forms a conspicuous part of the Pierre shale outcrop in the area under consideration.

The Sully is divided into three distinct lithologic units which are, in ascending order, the basal Crow Creek, the Agency-Oacoma, and the Verendrye zones. Because of their importance in any detailed study of this area, a separate discussion of each is given below:

#### The Crow Creek Zone

The Crow Creek zone has been identified only in the Missouri Valley and its tributaries. It can be traced from Gregory County northward to central Hughes County where it finally passes beneath the level of the Missouri River. It is a distinct horizon divided into two parts and easily recognized, a basal sandstone and an overlying marl:

Basal Sandstone: This bed is a brown laminated soft

Formations Exposed in the Area Occupied  
by  
the Medicine Butte Anticline

Thick-  
ness

Tertiary	Quaternary		Boulder clay, erratics, Sand and gravel terrace deposits.			
	Pleistocene					
CRETACEOUS P I E R R E F O R M A T I O N	Moberge Member		Yellow calcareous shale to chalk.	90' 245'		
	Virgin Ck. Member	Upper		Gray shale, gray concretions, and white "Indian Bead" concretions.	25' 142'	
		Lower		Hard gray shale, few concretions, numerous thin bentonite beds.	26' 145'	
	Sully Member		Verendrye	"Banded beds" Light to dark gray shale, abundant flat concretions, and thin bentonite beds.	88' 180'	
			Oacoma	Upper	Gray shales, with abundant iron manganese concretions and bentonite layers.	20' 60'
				Lower	Gray shales with few layers of iron manganese concre- tions and bentonite layers. Hard light gray siliceous shale	30' 50'
				Agency		
			Crow Creek	Marl		3'-14'
				Sandstone		4"-12"
	Gregory Member	Upper		Light Buff to dark gray shale with concretions and calcareous layers.	27' 125'	
		Lower		Impure light gray chalk	5' - 8'	
	Sharon Springs	Upper		Soft bluish-gray shale	9'-14'	
		Lower		Dark Bituminous shale, contains an abundance of fish scales	14'-34'	
			Niobrara	Chalk		

Figure 1

sandstone; it is very persistent and from 4 to 12 inches thick.

Marl Beds: These beds are an impure gray chalk or marl. They always occur in contact with the basal sandstone, being very persistent and missing in only one locality. The zone is from 3 to 14 feet thick.

### The Agency-Oacoma Zone

The Agency zone of the Sully Member is a hard, light gray, siliceous shale, and is prominent to the north in Dewey County.<sup>1</sup> Southward from Dewey County into the area under consideration the zone thins and loses its characteristics and grades into the Oacoma zone.

The Oacoma zone is probably the most prominent member of the Pierre formation because, first, it can be identified for long distances due to its black appearance caused by weathering of the iron-manganese concretions; second, it supports very little, if any, vegetation. The zone is characterized by shale, many bentonite beds and manganese concretions, and has been divided into two divisions--the upper and lower--primarily because the iron-manganese concretions are very numerous in the upper division, whereas the lower is nearly barren. The bentonite layers are also less numerous in the lower division.

The division point of the upper and lower Oacoma zone is a one to six inch layer of yellow bentonite that contains abundant biotite mica flakes, and is called the lower micaceous bentonite bed--the LMB of other reports.<sup>1</sup>

Aside from the concretions and bentonite layers, both the upper and lower divisions are gray shales. The zone is from 20 to 85 feet thick.

### The Verendrye Zone

The Verendrye zone is the uppermost part of the Sully

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1. Gries, op. cit., p. 16-17

member of the Pierre shale formation. It can be recognized by its banded appearance and brown coloration, caused by alternate beds of light gray flaky shales and dark gray gummy shales, and contains rusty limestone concretions. The contact with the underlying Agency-Oacoma is not definite, but has been placed at or near the top of the concentration of manganese concretions and bentonites in the upper Oacoma zone.<sup>1</sup>

#### The Virgin Creek Member

The Virgin Creek Member of the Pierre formation is divided into a lower and upper zone. The lower zone consists of medium hard, gray shale which weathers to small silvery flakes and is characterized by the presence of a large number of thin bentonite layers. The upper zone consists of a gray shale that weathers to gumbo, and contains concretions which appear to have been "worm eaten" and hollow cylindrical concretions known as "Indian beads." The Virgin Creek member is from 25 to 285 feet thick.

#### The Mobridge Member

The Mobridge member of the Pierre shale formation is not subdivided as are the preceding beds. It is composed of gray chalky shale and chalk, which weathers light buff. The member is from 90 to 235 feet thick and can be identified along graded unsurfaced county roads by the quick change in color from the regular gray to the light buff of the member. It is present on all the high buttes and forms the crest of most of the hills in the upland.

#### Tertiary Deposits

Tertiary sands and clays are found as scattered outliers on the tops of the higher hills of the area, such as Medicine Butte, north of Reliance; Red Butte, south of Lyman; and the buttes west of Lower Brule. The clays are either

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1. Wing, M. E. and Gries, J. P., Stratigraphy and Structure of the Chamberlain Section of the Missouri River Valley, S. Dak. State Geological Survey Report of Investigations No. 39, April, 1941.

GEOLOGIC MAP OF SOUTH DAKOTA

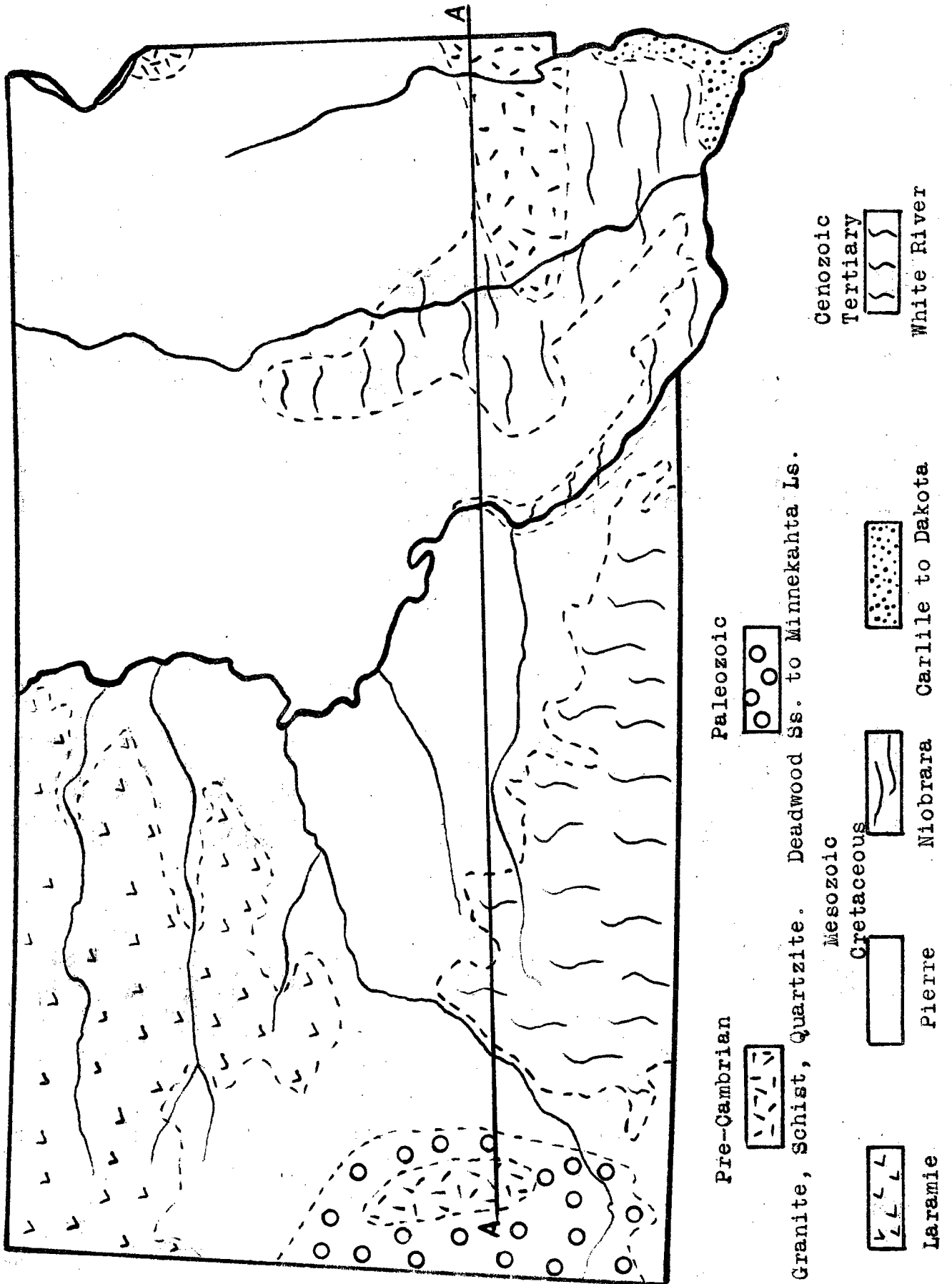


Figure 2

Oligocene or Miocene in age and the heavy green quartzite float strewn down the sides of the buttes is considered to be Arikaree (miocene age).

### Key Beds

For many years the Pierre shale was considered void of definite horizons which could be correlated or could serve as stratigraphic horizons with which to carry on geologic field investigations. In view of the fact that four-fifths of the state is underlain by the Pierre formation it was obvious that key horizons had to be found. In the attempt to solve this problem the State Geological Survey evolved the Missouri Valley section previously described.<sup>1</sup> The investigation of this problem brought to light certain horizons or key beds, and today the various members are referred to by name. Hence the term Pierre shale has been put in the background or seldom mentioned.

Crow Creek Sandstone: Several key beds are now fairly well known--the most important of these is the Crow Creek sandstone. The Crow Creek sandstone was first described by Searight (1937 p. 13) who noted its persistence in the outcropping shales along the Missouri River. In an unweathered condition the sandstone is probably nearly white, but it appears even in relatively fresh exposures as brown. The bed is laminated and as it case hardens and weathers further, it breaks down into numerous gently curved plates--one eighth inch or more in thickness.

The deposit averages from 8 to 12 inches thick, but has been observed as thin as four inches. Near the mouth of Medicine Creek it was only one inch thick, but this is not the usual situation.

Where the deposit is thick, its float is heavy laminated blocks, appearing as sheets cemented together. Many times the float is black; usually it is brown.

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1. Searight, W. V., Lithologic Stratigraphy of the Pierre Formation of the Missouri Valley in South Dakota. State Geological Survey Report of Investigations No. 27, June, 1937.

Crow Creek Marl: Associated with the sandstone and immediately above it is the Crow Creek Marl. The two beds taken together form a white to light gray band which can be spotted as far as 5000 feet away.

The Crow Creek marl is an impure chalk light gray in color. In grassed over slopes it can be seen as a band of yellow sod which frequently supports an abundant growth of wild yucca plants.

The marl is from 3 feet to 14 feet thick and in only one locality--T. 107 N., R. 74 W., in the vicinity of the Schafer Ranch--is it missing. However, the sandstone is present here.

The top of the marl is not a good mapping horizon because the contact with the overlying shale is not sharp. The bed is used, however, to spot the underlying sandstone.

Big Bentonite Bed: In the upper Oacoma horizon of the Sully member of the Pierre shale there occurs a big bentonite bed that is persistent throughout the area. This big bentonite bed consists of a layer of bentonite from 4 to 8 inches thick. Beneath it is a 2 inch bed of black shale which contains 1/2 to 1 inch iron-manganese concretions. Below this is another layer of bentonite which is 2 inches thick. These three beds then comprise the big bentonite bed, referred to as the B.B.B. in previous reports of the Geological Survey. The bed can be used as a key horizon, and it occurs about 8 feet below the Verendrye-Oacoma contact of the Sully Member.

On Medicine Creek in T. 107 N., R. 74 and 75 W., where both the Crow Creek sandstone and the big bentonite bed are exposed, several elevations on each were taken and the interval between them was found to be 75 feet. On the west side of the Big Bend of the Missouri River at Farm Station in T. 108 and 109 W., R. 74 W., the interval is 51 feet between the two beds. On Medicine Creek in T. 106 N., R. 74 W., the interval between the Crow Creek sandstone and the top of the Manganese zone, or the Verendrye-Oacoma contact varies from 75 to 83 feet.

Rusty Beds: On Cedar Creek in T. 108 N., R. 76 W.,

there is a pair of parallel rusty bands which are 13 feet above the big bentonite bed. The interval between the parallel rusty bands and the Crow Creek sandstone is 98 feet. These intervals were used for reducing elevations on the above key beds to the datum of the Crow Creek sandstone wherever the latter was obscured.



## II. THE SUBSURFACE FORMATIONS

### Introduction

Literature that describes the subsurface formations of the central Great Plains usually goes into some detail about the formations exposed in the Black Hills. The section along Rapid Creek offers certain criteria of the subsurface formations which underlie the surrounding plains but it is over 200 miles west of the area under discussion, and consequently is of little value below the Cretaceous formations.

A rise in the basement rocks eastward will cause the lower formations to wedge out. An eastern source of sediments and unknown barriers between basins of sedimentation may occur in this distance. The Black Hills section should therefore be correlated to this area with many reservations. There is no known way short of drilling to find which formations lie on the "granite." Some light can be thrown on subsurface conditions, however, by the logs of deep wells drilled in the neighborhood.

### Stratigraphy

The stratigraphy of the Cretaceous formations is fairly well known through the Dakota-Lakota sand series in this area, because several wells, drilled for artesian water, have penetrated it. Representatives of most of the Cretaceous formations of the columnar section in the Black Hills are present but have changed somewhat in character and thickness.

Four deep wells have been drilled in western South Dakota from which a complete set of cuttings are available. Though they are not in the immediate vicinity of the Medicine Butte Anticline, the nearest one being 80 miles northwest, they throw considerable light on the formations which may be encountered in drilling the Medicine Butte Anticline. They show that the formations below the Cretaceous, as exposed in the Black Hills, thin eastward; that the Red Beds disappear entirely, and that a thicker limestone is present in the Missouri River area than is exposed in the Black Hills sections. Figure 2.

The four wells are located as follows:

Company	Farm	No.	County	Sec.	T.	R.	Elev.	Depth
Gypsy Oil Company	Hunter	1	Pennington	28	3N	16E	2956'	5001'
U. S. Gov't.	Airport	2	Pennington	18	2N	9E		4424'
Carter Oil Company		1	Potter	34	118N	78W	1865'	3611'
Carter Oil Company		2	Stanley	12	9N	27E	1786'	3890'

Aside from the deep test records the following wells are of considerable value:

U. S. Gov't.	Airport	a	Hughes	35	111N	79W		2365'
	Stan. Butte	b	Stanley	9	7N	27E	1958'	3508'

a Finished below Cretaceous rocks.  
b Drillers log, no samples available.

Although these well records are too far distant to serve as an accurate guide to the formations below the Cretaceous, in the area under discussion, they do serve to show the manner in which these beds change in character away from the Black Hills outcrops and make the common practice of carrying Black Hills formations unchanged into the correlations of Missouri Valley well logs very questionable.

The logs of the Gypsy Oil Company's Hunter No. 1 well and the Rapid City Airport No. 2 well show that the formations penetrated in the wells correlate with the columnar section of the Black Hills except that the Hills section is much thicker.

The log of the Carter Oil Company's No. 2 well shows the absence of Red Beds and a thickening of the Paleozoic limestone section. The Standing Butte well, 12 miles to the west according to the driller's log, penetrated the limestone at about the same depth. Only a few scattered samples were saved from this well and it is worth noting

that the Red Beds reported by the driller do not occur in the complete sample set from the nearby Carter No. 2.

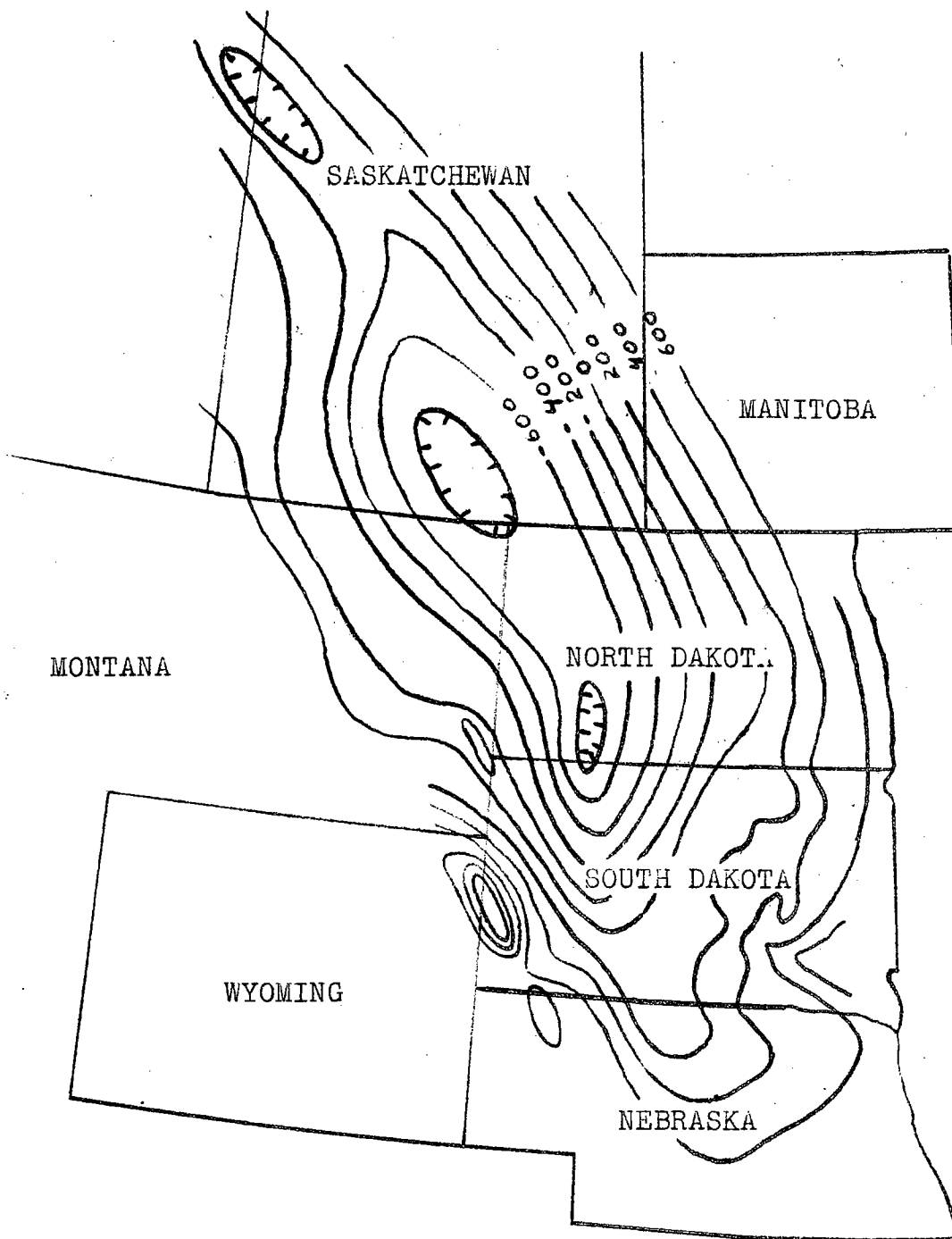
The logs of four wells in the immediate vicinity of the Medicine Butte Anticline (see appendix) offer information on the Cretaceous rocks through the Dakota-Lakota group. They show the general sequence of the formations as exposed in the Black Hills and along the Missouri River from Sioux City, Iowa, to Fort Thompson.

The four wells are located as follows:

Wells in the Immediate  
Vicinity of Medicine Butte Anticline

Company	Farm	No.	County	Sec.	T.	R.	Elev.	Depth
Chamberlain			Brule	15	104	71	1547'	983'
Carpenter		1	Brule	35	104	70	1583'	907'
McClure		1	Lyman	31	108	78	1917'	1623'
U.S.Gov't.	Mn. Plant	1	Lyman	9	104	72	1539'	872'

STRUCTURE MAP OF THE MOOSEJAW SYNCLINORIUM



Contoured on the Dakota Sandstone  
(After Huntley)

Figure 3

## IDENTIFICATION OF SOUTH DAKOTA FORMATIONS IN DRILL CUTTINGS

The following key beds or prominent horizons can be identified by their characteristics on the basis of lithology, from the study of drill cuttings as they are encountered during drilling operations.

The following descriptions of the formations are intended primarily as an aid to the identification of the cuttings in the field at a drilling site by the operating crew or others interested. It is hoped that the descriptions will incite an interest in "grabbing samples" as even today samples are "grabbed" under duress.

### The Niobrara Formation

The Niobrara formation appears in drill cutting as a light gray shaley chalk matrix, speckled throughout with round white chalk grains, giving the cuttings a porphyritic appearance.

In cross section the white chalk grains are distributed in the matrix as lenticles and bands giving it a gneissoid texture. In the outcrop, the Niobrara chalk is bleached white with a tan stain throughout. Upon comparative examination it can be seen that it is the gray shaley chalk matrix that turns to tan whereas the chalk grains remain white.

The Niobrara chalk formation is an ideal core drilling horizon because it is very persistent, easily recognized, and lies at comparatively shallow depths.

### The Greenhorn Formation

The Greenhorn formation in drill cuttings, is analogous to the Niobrara chalk in appearance except that the matrix is black and slightly harder. In Greenhorn cuttings there are also particles of crystalline limestone. The limestone is made up of cemented grains of calcite and few spicules of *Inoceranus* shells. Black speckled calcareous gumbo is often found in the cuttings.

## The Dakota-Lakota Group

The Dakota formation, as observed in drill cuttings, ranges from a loose sand to a tightly cemented sandstone. The individual grains of quartz are quite even in size, but small, and are rounded to angular in shape. In rotary cuttings only about 10% of the sample is composed of sandstone and loose sand. Individual pieces of quartz are common; some pieces of sandstone are calcareous. The position of the Dakota sandstone can usually be identified during drilling operations by the enormous flow of water encountered, usually artesian, when the formation is drilled into.

The Fuson formation lies between the Dakota and the Lakota formation in the Black Hills outcrops. It appears as a light gray clayey shale with a sprinkling of maroon shale in the cuttings; the former contains minute particles of black material throughout.

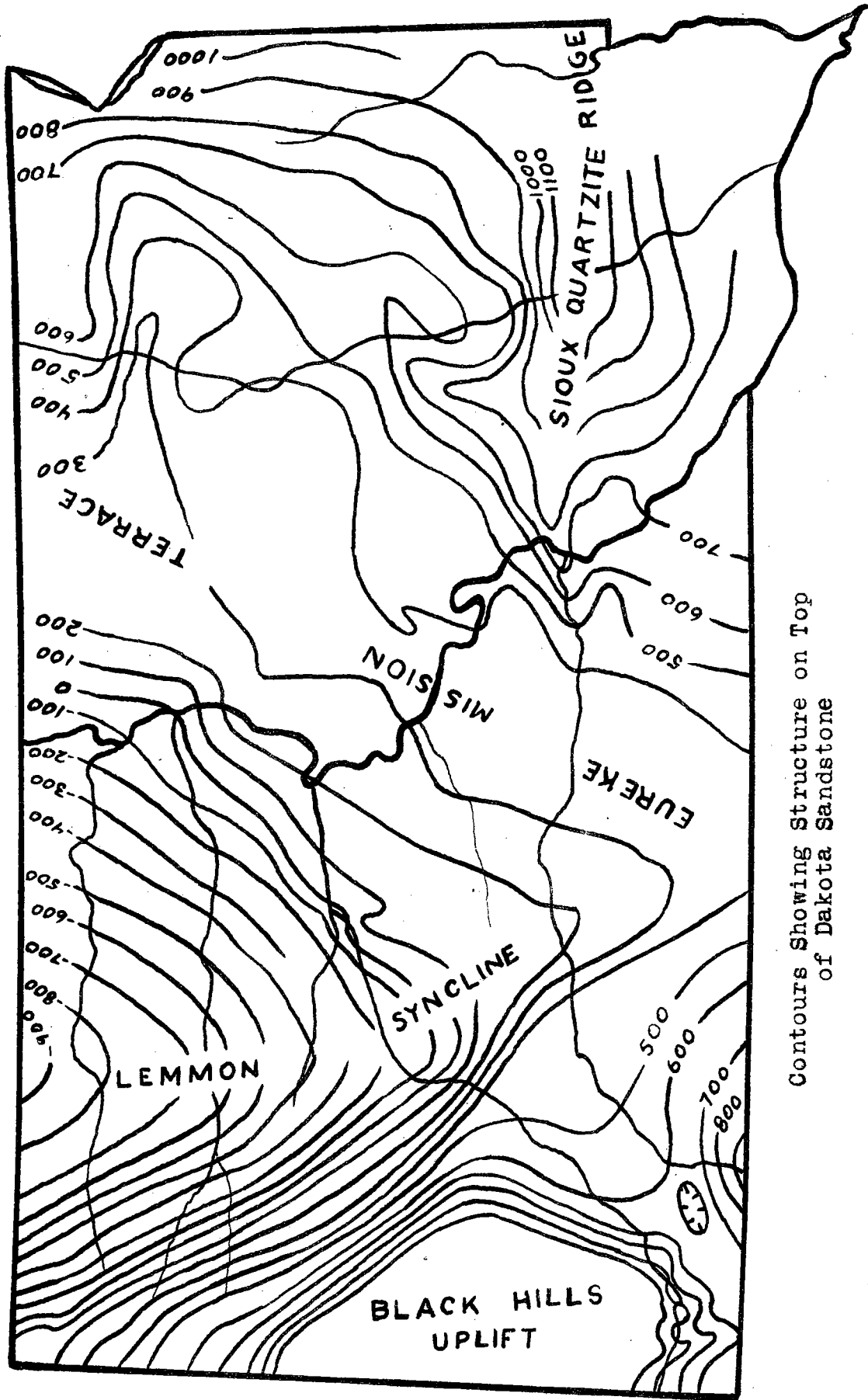
In the outcrop the Fuson is a colored clay, varying in color through gray, maroon, purple and brown. Fire clays have been described from this formation in the vicinity of Rapid City. The deposits also contain interbedded layers of sandstone.

The Lakota formation is primarily a sandstone, so poorly cemented that in the cuttings only about 10% of the material is collected. The sandstone, as observed, is a white to clear calcareous sandstone; however some cuttings have a reddish cast and are not calcareous. Loose fine sand and large (1/16") round quartz grains are common.

In the well cuttings, sandstone containing pellets and crystals of pyrite were found at what appears to be the same horizon. As these do not appear in the Dakota sandstones it is probable that they can be used as an indicator for the Lakota.

In the outcrop the Lakota formation is a deposit of several sandstones separated by shales, each layer varying in thickness.

STRUCTURE MAP OF SOUTH DAKOTA



Contours Showing Structure on Top  
of Dakota Sandstone

Figure 4

### The Morrison Formation

When the Morrison formation is present in cuttings it appears as a varicolored clay. The colors are maroon, purple, lavender, yellow, buff, gray, pale green, brown, and black. Sometimes most colors are missing except gray, yellow and maroon. The material itself is a dense clay.

### The Spearfish Formation

The Spearfish formation or "Red Beds" always speak for themselves in the cuttings. This thick deposit of brick red shales and sands is duplicated only in the underlying Opeche and locally in some bright red sandstones in the top of the Sundance formation. Along with the red shales are usually pieces of gypsum and sandstones.

### The Minnekahta Formation

The Minnekahta formation can be recognized because it is the first limestone to be encountered after the upper "Red Beds" have been drilled into, and in an ideal section, such as the Black Hills column, there are red beds on either side of it. The Minnekahta is a pale pink dense limestone. In the cuttings it usually makes about 90% of the sample.

### The Pahasapa Formation

When the Pahasapa formation is drilled into, it can be identified as a white, dense limestone and white, crystalline limestone. All of the material in the sample is composed of pieces or chips of the limestone. Other stray cuttings are seldom present.

An outcrop of the Pahasapa formation can easily be recognized because it always forms the higher white limestone cliffs in mountainous areas.



## STRUCTURE

### Regional

The regional structure of most of South Dakota has been determined from the logs and cuttings of wells drilled to the Dakota-Lakota sand zone in search of artesian water. Figure 4 shows the attitude of the Dakota sandstone as indicated by contouring the elevations of the first artesian water sand in these wells.

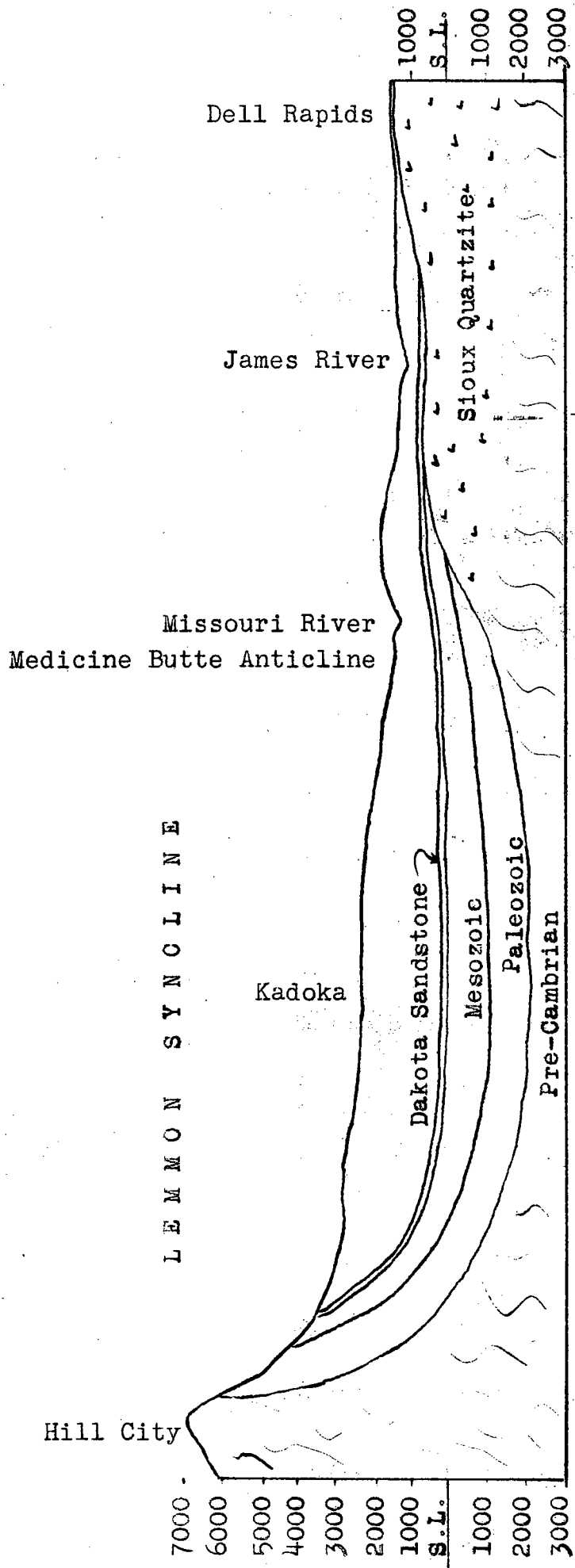
The Lemmon Syncline, the dominant structure, is a large plunging trough (Figure 5), which is the southern portion of the Moosejaw Synclinorium (Figure 3). This synclinorium is the major structural basin in the northern great plains. It begins northwest of the city of Moosejaw in Saskatchewan, Canada; trends southeast through North Dakota; then south through the city of Lemmon, South Dakota; and finally ends somewhere in Nebraska. It is bounded on the east by the Souris River gas field, Maleta, Manitoba; the Bottineau Gas Field, Westhope, North Dakota; and the Eureka-Mission Terrace in South Dakota. On the west it is bounded by the Black Hills uplift, which is made up of three distinct structures; The Chadron Anticline in Nebraska, the Black Hills Proper in South Dakota and the Cedar Creek Anticline in Montana.

The Eureka-Mission Terrace is a broad structural flat extending in a northeast-southwest direction across the state. The flatness of the formation is shown by the similarity of elevations on the Dakota water bearing sandstone (Figure 4). The terrace is some 60 miles wide, sloping very gently northwest at an approximate rate of one to two feet per mile into the Lemmon Syncline.

The Medicine Butte Anticline lies on the east side or rear of the Eureka-Mission Terrace.

### Local

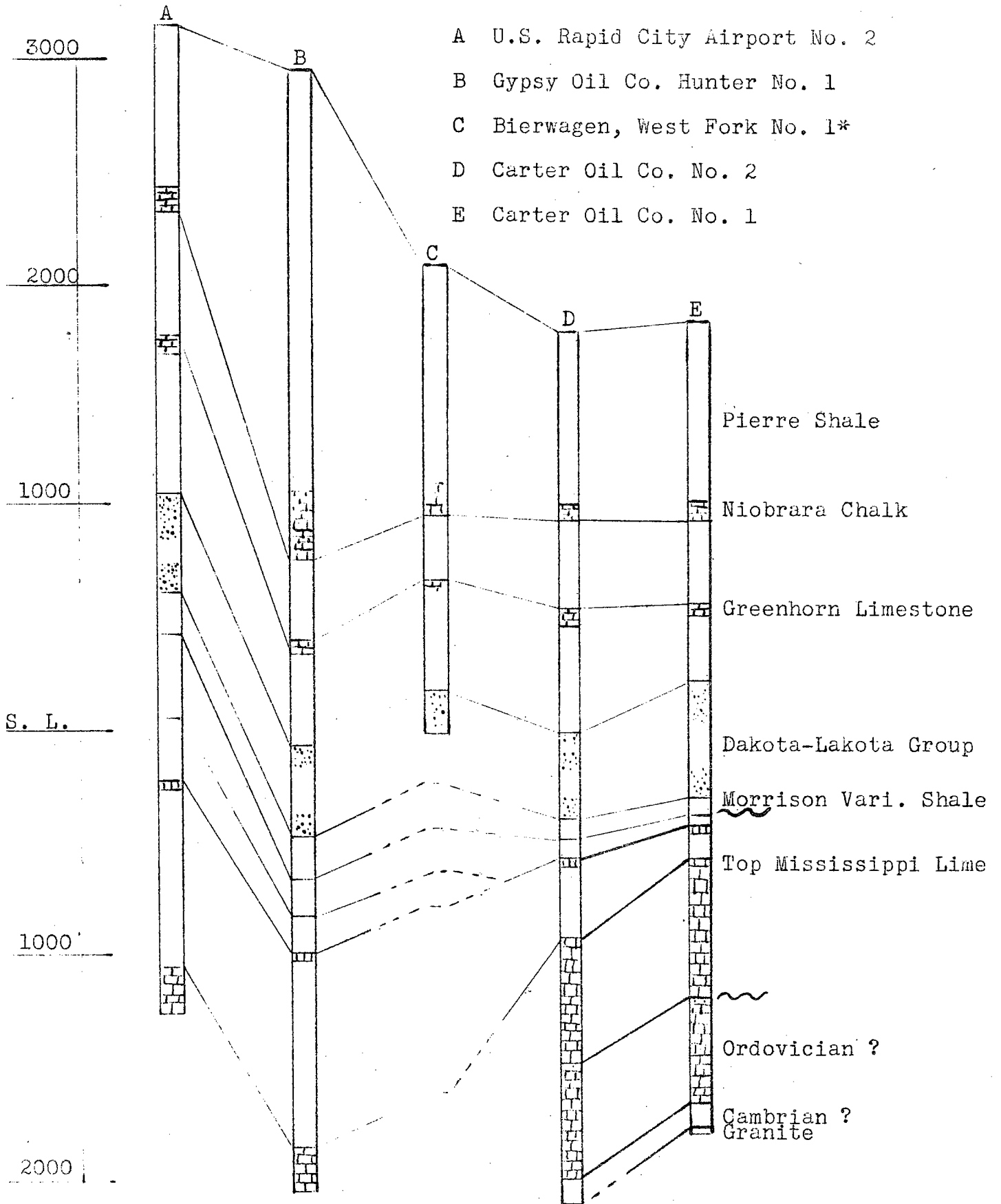
The Medicine Butte Anticline is an elongated dome whose axis lies in a northwest-southeast direction, roughly parallel to the axis of the Lemmon Syncline. The reverse or critical dip is toward the east and from elevations taken



Line A-A, Fig. 2.

A Cross-section of South Dakota from Hill City to Dell Rapids

Figure 5



\*Haakon County, sec. 11, T. 6 N., R. 21 E.,  
 Elev. 2079', T. Depth 2100'

Figure 6

on the Crow Creek sandstone it amounts to 60 feet in 4 miles. The highest elevation on the sandstone was observed to be 1550 feet above sea level; whereas in the area south of Fort Thompson the sandstone has an elevation of 1480 feet.

In view of the fact that mapping was limited to the outcropping of the key bed in the bluffs of the Missouri River and its tributaries the highest parts of the structure could not be mapped. Enough elevations were obtained, however, to show that the structure has closure on the north, east, and south, the critical directions. The north portion shows a closure of more than 60 feet in the Big Bend Country. The closure (exposed along the White River) of the south portion of the structure is 40 feet.

The axis of the Medicine Butte Anticline is 35 miles long. It begins at the northwest curve of the Big Bend in the Missouri and extends to a point 2 miles west of the town of Oacoma. Reference to the accompanying map will show the size and shape of the Anticline. It is a compound structural feature in which the main fold is modified by local warpings, such as small anticlines and synclines.

Oacoma Syncline: In the vicinity of Oacoma and northward the eastern flank is indicated by a syncline about 5 miles long and one mile wide, which in turn is surrounded by small anticlinal structures.

The most prominent of these small anticlines is in sec. 33 and 34, T. 105 N., R. 72 W., which is apparently on the main axis of the Medicine Butte Anticline. The reverse dip is 40 feet in three miles or 13 feet per mile, southwest into the Oacoma Syncline. This dip is apparently from the main axis of the Medicine Butte Anticline. The Oacoma syncline, as mapped on the Crow Creek sandstone, is further emphasized by the fact that the artesian water horizon or Dakota sandstone is low in wells at Oacoma and in a well five miles north in sec. 30, T. 105 N., R. 71 W. In these wells the first artesian sand (Dakota) was reached at elevations of 555 feet and 584 feet respectively.

Three miles northwest of Oacoma, on the axis of the main fold, the Dakota sandstone is high in the U. S. Government's Well at the Manganese Plant lying at an elevation of 749 feet. The difference in elevation between the Manganese

Plant well and the Oacoma well is 95 feet signifying that the reverse dip increases with depth.

The Oacoma syncline may continue northwest, paralleling the axis of the Medicine Butte Anticline and connect with another syncline which was mapped in the southwest part of T. 107 N., R. 72 W. The lack of outcrops prevented the mapping of the south closure in the latter.

Bull Creek Anticline: About  $3\frac{1}{2}$  miles southwest of Oacoma is a narrow structural high. Its axis lies in a northwest-southeast direction parallel to the Medicine Butte Anticline. In the northern part of T. 103 N., R. 72 W., the axis turns southwest. The axis is about 10 miles long and has a closure in the southwest part of T. 103 N., R. 72 W. in the vicinity of Bull Creek, south of the White River.

The top and western flank of the Medicine Butte Anticline could not be defined because its topography is upland and key beds are not exposed. However, the regional structure shows that a west dip is present because the Dakota sandstone slopes 15 feet per mile into the Lemmon syncline. The dip of the Crow Creek sandstone is 15 feet per mile west, from a point north of Medicine Butte to Medicine Creek. There is also a west dip in the valley of the White River.

## GEOPHYSICAL SURVEYS

The entire region around the Medicine Butte Anticline has been surveyed with the magnetometer.<sup>1</sup> The full significance of the magnetic information is not clearly understood, but it can be noted by comparing the structural survey with the magnetic intensities that there is a close agreement between the anticline as mapped and the trend of the magnetic highs of the region, (Figure 7).

A magnetic low in T. 107 and 108 N., R. 75 and 76 W. corresponds to a low area on the west flank of the Medicine Butte Anticline which was mapped in this area.

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1. Tullis, E. L., Magnetometer Surveys During 1941. State Geological Survey Report of Investigations No. 42, 1942.

## OIL AND GAS POSSIBILITIES OF THE MEDICINE BUTTE ANTICLINE

The Medicine Butte Anticline is the type of structure that is favorable for the accumulation of oil and gas.

First, it is a type of structure comparable to producing structures in the mid-continent oil fields. It is a plains type structure because its closure is not great compared to structures that lie near mountainous areas, which are arched by the mountain folding. In some fields of the plains type the surface expression of the structure is so slight that they are discernable only by accurate mapping. In the Medicine Butte Anticline dips of the strata can be seen in the Big Bend Country and White River Valley. In other parts of the basin they are not obvious until mapped.

Second, regional structure is probably one of the most essential factors in the accumulation of oil. In this respect the Medicine Butte structure is favorably located since it is on the edge of the Lemmon syncline, a regional structural basin. Usually regional basins are rimmed by oil and gas fields, and it should be noted that the natural gas localities of the state rim the east side of the Lemmon syncline. Although the anticlines at Pierre are nearer the axis of the basin than the Medicine Butte Anticline, they are en echelon with each other and their axes have the same northwest-southeast direction.

### Mechanics of Oil Accumulation

It is probable that the origin of oil occurs in the regional structural basins, from whence it travels or migrates over long distances up the dip, through porous strata such as sandstones and porous limestones.

The migration of oil is assisted by the connate water in the strata, the porosity of the rocks, gravity separation of fluids and capillarity. Since the surface tension of water is greater than oil, the latter is always driven out of the pore spaces and moved upward.

Eventually it is trapped and migration ceases. Anticlines form favorable traps in which oil and gas can accumu-

MAGNETIC MAP OF THE MEDICINE BUTTE ANTICLINE

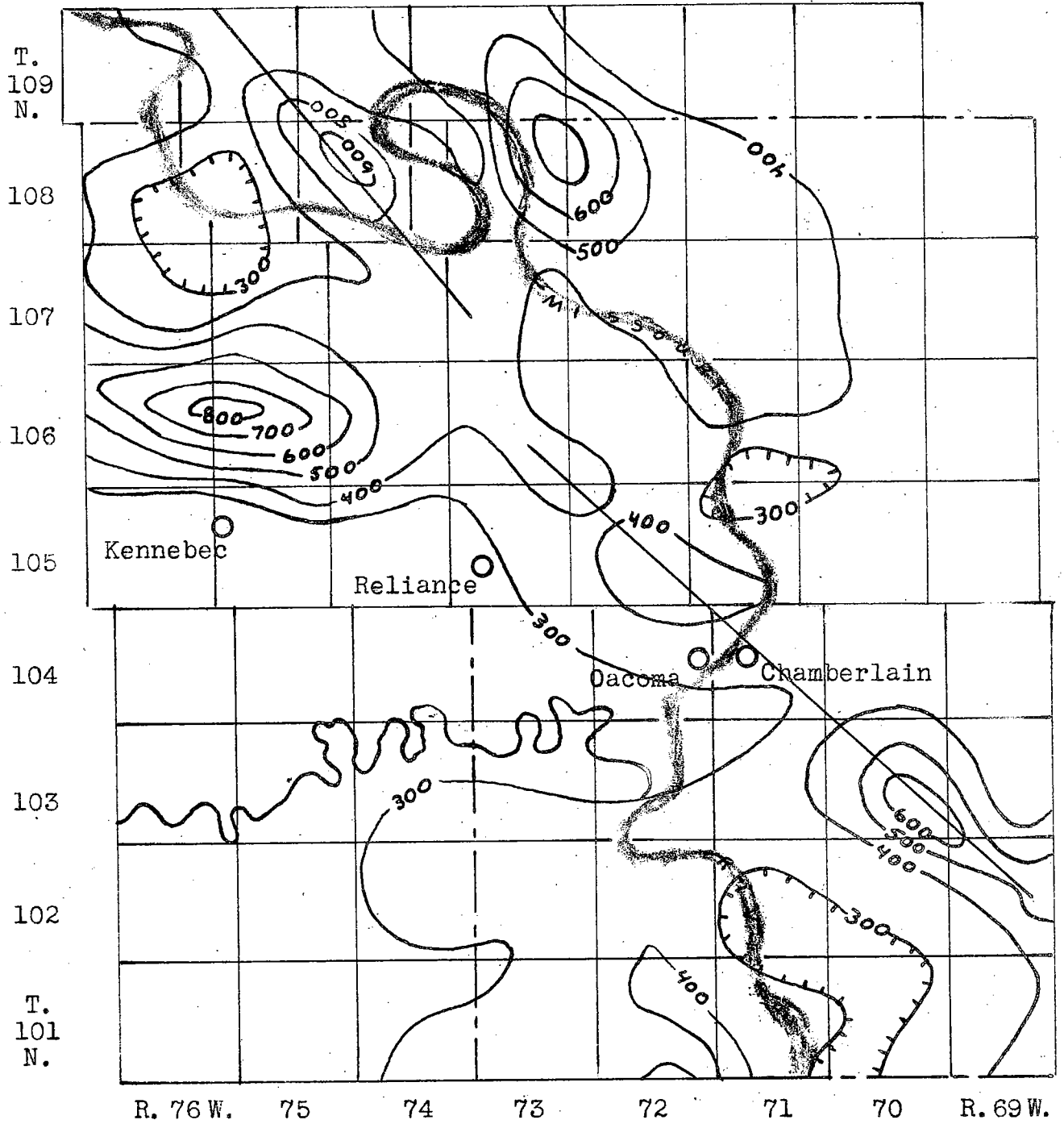


Figure 7



late. Under ideal conditions the trap itself is the closure or where the regional dip has reversed and the migrating oil and gas can go no farther. Hence it forms an oil pool.

### Possible Oil Bearing Horizons

The Niobrara Formation is the first horizon that might contain oil and gas in the anticline. Gas is present in three wells on the Bull Creek Anticline. Two of the wells are in sec. 1, T. 102 N., R. 73 W., and the other is in sec. 23, T. 102 N., R. 73 W.

Gas has been reported in widely separated areas in South Dakota in the Niobrara formation. In Stanley County it was present in the Standing Butte and Meers Wells; in Haakon County--in the West Fork Well; in Charles Mix County--in a well near Wagner; and in wells at Rumford in Fall River County.

The Dakota-Lakota zone is a series of sandstones with interbedded shales that underlie the area and are horizons which might be oil bearing. The sandstones always contain water, usually artesian and have the porosity requisite for ready migration of oil and gas, as is indicated by the active circulation of water. These formations have yielded oil shows in the Standing Butte well and Rapid City Airport well. Gas production is common along with artesian water, both along the east side of the Lemmon syncline and on the Eureka-Mission Terrace.

Paleozoic Formations: No deep wells have been drilled nearer than 80 miles to the Medicine Butte Anticline, hence there is no immediate data on the Paleozoic formations which may lie beneath the Medicine Butte structure. However, it is assumed that sandstones and limestones are present because of the interval between the base of the Lakota and the "granite" which may lie at a depth of about 2000 feet, as determined from a composite of Lakota-Pre-Cambrian intervals from wells both east and west of the Missouri which did reach "granite!"

## Physiography

It might be pointed out that the course of the Missouri River from the Big Bend to the mouth of the White River is out of line, signifying that the river found its grade around the east side of the Medicine Butte Anticline instead of being located where it is by the transgressing glacier. The movement of the ice would have pushed the river out of line to the westward as can be seen by the course of the river throughout the state.

## GEOGRAPHIC FACTORS

The axis of the Medicine Butte Anticline is easily accessible because it is traversed by U. S. Highway No. 16, a paved, all weather road which is the main artery of traffic between the Black Hills, Sioux Falls and Chicago. The entire area has also a section-line net work of county and township roads which give access to all parts of the axis of the structure. A few of the roads have gravel surfaces; others are graded dirt roads usable in dry weather. Smooth rolling topography allows roads to be built almost anywhere in the area except in the brakes of the Missouri River and its large tributaries.

The Chicago, Milwaukee, St. Paul and Pacific Railroad serves that part of the state with stations at Kennebec, Reliance, Lyman, and Oacoma, from which all parts of the structure can be reached.

### Water

The area under discussion is a semi-arid region and quite dry especially in the summer.

There are no large streams near the top of the structure, and the large creeks that are tributary to the Missouri River become dry early in the summer. Except for a few upland ponds, most of the standing water is impounded behind dams of which there are many. Usually sufficient water for drilling can be obtained in this manner.

Well water is not obtainable in the Pierre shale which is the surface formation; however there are shallow wells in local gravel deposits, which many times supply local needs.

The largest available source from which water can be obtained is the Dakota sandstone which can be reached by drilling about 1400 feet more or less. The water is usually artesian and flows with considerable pressure in the valleys.

It will not flow on the uplands since its head will raise it only to an elevation of about 1800 feet.<sup>1</sup>

The water of the Oacoma city well contains about 1894 parts per million of solids. The following is the water analysis of the Oacoma city well:<sup>2</sup>

	<u>Parts Per Million</u>
Total Solids	1894
SiO <sub>2</sub>	21
SO <sub>4</sub> <sup>2</sup>	1050
Cl	104
Fl	2.8
Ca	330
Mg	75
CaCO <sub>3</sub>	1135
Fe	11.0
Mn	0.2
Alkalinity M.O.	137
Alkalinity Phen.	0.0

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1. Rothrock, E. P. and Robinson, T. W., Jr., Artesian Conditions in West-Central South Dakota, South Dakota Geological Survey Report of Investigations No. 26, 1936.
  2. Frary, Guy G., Public Water Supplies in South Dakota, 1939.

APPENDIX

LOGS OF DEEP WELLS USED IN THIS REPORT

LOG

U. S. Government  
Rapid City Airport #2  
Pennington County, South Dakota  
Sec. 18, T. 2 N., R. 9 E.

- 0- 290 No samples.  
290- 350 Gray shale and dark crystalline limestone.  
350- 430 Dark crystalline limestone, loose quartz grains  
and pieces of red sandstone at base.  
430- 510 Gray shale, pieces of crystalline limestone in  
upper part, pieces of shell.  
510- 570 Gray shale and calcareous gray gumbo.  
570- 630 Gray shale.  
630- 660 Gray shale, gray speckled chalk and pieces of  
dense limestone.  
660- 700 Gray shale.  
700- 820 Chalk speckled gray to black, pieces of gray  
shale.  
820- 900 Gray shale, calcareous gumbo, calcareous gray  
shale and pieces of chalk.  
900-1020 Calcareous gray shale, calcareous gray gumbo and  
gray shale.  
1020-1050 Red sandy limestone, white limestone, pyrite  
flakes.  
1050-1070 Black shale and pieces of limestone plus small  
amounts of above.  
1070-1290 Black shale.  
1290-1390 Black shale, some slightly calcareous.  
1390-1450 Black calcareous gumbo.  
1450-1580 Dark gray and black shale, some slightly cal-  
careous.  
1580-1720 Dark gray shale.  
1720-1750 Black shale.  
1750-2120 Dark gray shale, (show of oil in sandstone at  
2090-2100).  
2120-2180 Pieces of sandstone, shales, gray, dark gray and  
black.  
2180-2235 Gray and dark gray shale, scattered pieces of  
sandstone.  
2235-2280 Shales, dark gray, gray and black, few pieces of  
sandstone at 55-65.  
2280-2281 Shales, gray and red, (circulated 45 minutes).  
2280-2320 Shales gray and pieces of sandstone.  
2320-2460 Gray shales, yellow shale at 2320-30, pieces of  
sandstone at 2410-20 and 40-50.  
2460-2480 Shales gray and black, few pieces of black speck-  
led chalk.  
2480-2510 Shales, gray and light gray, calcareous sandstone  
at 2490-2510. Pyrite cemented sandstone.  
2510-2520 Brown dense limestone and gray shale.

- 2520-2610 Shales, gray, maroon, yellow, pieces of limestone and sandstone. No maroon or yellow shale below 2580.
- 2610-2650 Shales, gray.
- 2650-2690 Shales, gray, light gray, pieces of brownish yellow shale, pieces of calcareous sandstone at 50-70.
- 2690-2710 Shales, light gray, gray and varicolored pieces of sandstone.
- 2710-2720 Limestone, sandstone, shales, gray, light gray.
- 2720-2790 Gray shale, calcareous shale.
- 2790-2910 Calcareous gray shales, gray shales, pieces of yellow shale at 2840-60, pieces of sandstone in lower part, maroon and yellow shale at 2900-10.
- 2910-3080 Gray shale, calcareous gray shale in upper part, few pieces of sandstone scattered, calcareous black shale at 2970-80 calcareous gray shale at 3010-20.
- 3080-3200 Shales, gray, red, pieces of sandstone throughout red sandy shale, yellow shale at 3110-20, gypsum at 3140-50.
- 3200-3290 Shales, red, gray, pieces of gypsum, red sandy shale.
- 3290-3320 Shale, red, gray, red calcareous mud, sandstone, pieces of gypsum.
- 3320-3380 Shales, red, gray, slightly calcareous gray, pieces of sandstone, pieces of white dense limestone.
- 3380-3410 Limestone, dense, white, some gray shale.
- 3410-3450 Shales, red, gray, red sandy shale, red mud, pieces of limestone.
- 3450-3500 Shales, gray, sandy, some calcareous gray shale, red mud, pieces of red shale.
- 3500-3550 Shales, gray pieces of red sandstone, sandstone, red shale.
- 3550-3590 White limestone, gray calcareous shale, red shale, white sandstone.
- 3590-3620 White dolomitic limestone, gray shale.
- 3620-3670 Gray shale, pieces of white dolomitic limestone, pieces of red shale, red sandstone at base.
- 3670-3790 Gray shale, red shale, anhydrite, red sandstone, pieces of limestone, white sandstone.
- 3790-3860 Gray shale, anhydrite, red shale and sandstone, loose quartz grains at 3820-30.
- 3860-3880 Shales, gray, red, loose quartz, pieces of sandstone.
- 3880-3910 White dense limestone; shales, red, gray; pieces of anhydrite.
- 3910-3950 Red shale anhydrite, gray sandy shale.
- 3950-3980 Red and maroon shale, white sandstone, red lime-

stone.

3980-3990 White porous limestone, gray shale.

3990-4000 Dark gray shale, red and gray shale.

4000-4040 White sandstone at top, white dense limestone, red shale.

4040-4080 Red shale, dense dolomitic limestone, gray sandstone.

4080-4100 Dense dolomitic limestone, white sandstone, red shale at base.

4100-4150 White dense dolomitic limestone, scattered red and gray shales.

4150-4180 Red shale at top, dolomitic limestone, sandstone, pale green shale.

4180-4190 White massive limestone.

4190-4210 Conglomeration, loose quartz grains, red shale at 4205-10.

4210-4345 White dense limestone, crystalline limestone, scattered red shales.

4345-4395 White and pink limestone.

4395-4425 White and pink limestone and dolomite.

4425 Total depth.



LOG

Gypsy Oil Co.

Hunter #1

Pennington County, South Dakota

NE $\frac{1}{4}$ SW $\frac{1}{4}$  sec. 28, T. 3 N., R. 16 E.

Curb Elevation 2956.8' ( by S. Dak. Geological Survey)

0-1900 Shale, gray.  
1900-2120 Shale, gray, chalky.  
2120-2170 Chalk, gray to white.  
2170-2390 Shale, gray; sandy shale; and thin fine sands.  
2390-2563 Shale, dark gray to black; chalky below 2470'.  
2563-2575 Limestone, brown, soft.  
2575-2610 Shale, dark gray, limy.  
2610-2690 Shale, greenish-gray, silty.  
2690-2875 Shale, dark gray to black, chalky.  
2875-3024 Shale, greenish-gray to black; silty shale; sandy shale; and thin fine sands.  
3024-3054 Sand, medium fineness, porous. Drill stem tester showed 1400' of fresh water in one hour, 3041'.  
3054-3077 Shale, greenish-gray.  
3077-3082 Sand, coarse.  
3082-3145 Shales, gray, drab, maroon; layers of sandy shale.  
3145-3154 Shale, dark gray, silty.  
3154-3178 Shale, dark gray; thin limestones, gray brown.  
3178-3313 Shale, gray, silty to sandy.  
3313-3323 Shale, dark gray; thin limestones, gray brown.  
3323-3325 Sand, pyrite cement.  
3325-3420 Sand, medium fineness, porous; layers of shale toward base. Drill stem tester showed 2300' fresh water in one hour, 3325'.  
3420-3445 Shales and siltstones, green.  
3445-3460 Shales and clays, red, white, brown, and green.  
3460-3488 Sand, coarse, porous. Drill stem tester showed 3000' fresh water in fifteen minutes, 3461'.  
3488-3495 Shales, gray to green, sandy.  
3495-3530 Sand, fine, varicolored.  
3530-3767 Shales, siltstones, and fine sands. Green.  
3767-3836 Sand, fine, and sandy shale, pink to red.  
3836-3950 Shale, red, gypsiferous.  
3950-3980 Limestone, dense, pink to white.  
3980-4080 Shales, red. Lower part silty to sandy.  
4080-4082 Anhydrite.  
4082-4121 Limestone, dense, white to pink.  
4121-4520 Interbedded anhydrite, red shale, green shale, sandy shale, thin sands, and thin limes.  
4520-4600 Limestone, brown; with thin fine sands and rare anhydrite. Drilled with cable tools below 4573'. Nine inch casing cemented at 4513'. One-half bailer of dilute water per hour, 4520-4580'.

4600-4660 Interbedded limy sand and sandy lime, brown.  
 4660-4693 Shale, red brown, with thin white limestones.  
 4693-4725 Limestone, dense, white to pink.  
 4725-4734 Shales, red, green, yellow, and purple.  
 4734-4780 Limestone, white to brown.  
 4780-4785 Shales, red, yellow, and green.  
 4785-4812 Limestone, bright red at top, light brown below.  
 4812-4830 Shales and fine sands, interbedded with variegated  
           clays.  
 4830-4934 Limestone, dense to crystalline, white, cream,  
           and light brown. Oolitic at base. Fresh water  
           rose 3850' from porous zone 4855-4872'.  
 4934-5001 Dolomite, finely crystalline, porous. Fresh  
           water rose 4000' from porous zone 4934'.  
       5001 Total Depth.

Note: This log is compiled from the original cuttings and agrees with the log of this well published in Report of Investigations No. 4, Logs of Some Deep Wells in Western South Dakota, March, 1936.

Due to an error of 200 feet in compilation, the log of this well, published in Report of Investigations No. 39, Stratigraphy and Structure of the Chamberlain Section of the Missouri River Valley, by M. E. Wing and J. P. Gries, April, 1941, will not agree with the log published here and in Report of Investigations No. 4.

LOG

U. S. Government

Manganese Plant #1

Lyman County, South Dakota

SW $\frac{1}{4}$ NE $\frac{1}{4}$  sec. 9, T. 104 N., R. 72 W.

Curb Elevation 1539'

- 0- 20 Yellow clay.
- 20-270 Blue shale.
- 270-330 Soft chalk rock.
- 330-400 Dark shale 335-336, one foot of rock.
- 400-465 Hard shale 368-370, 2' 3" of rock.
- 465-495 Shale.
- 495-535 Medium shale.
- 535-575 Shelly rock, hard shells being only a few apart  
and medium hard rock from 543-548.  
Very hard rock 560-561 feet.
- 575-620 Shale with a few hard shells.
- 620-678 Shale with a very hard shell of a few inches at  
678 feet.
- 678-720 Shale formation with a few hard shells of rock.
- 720-751 Hard shale with hard shells or rock.
- 751-767 Hard shell rock a few feet apart.
- 767-780 Very hard rock from 767-768 feet in dark shale  
formation.
- 780-800 Some sand rock from 790-800 feet and good sandstone  
from 800 feet.
- 800-860 Sandstone.
- 860-872 Shale.

## LOG

Carter Oil Company  
Stratigraphic Well #1  
Potter County, South Dakota  
C-NW $\frac{1}{4}$ NE $\frac{1}{4}$  sec. 34, T. 118 N., R. 78 W.  
Curb Elevation 1865'

0- 50 Gravel, clay, alkali.  
50- 120 Clays, loose quartz.  
120- 230 Clays, sand.  
230- 370 Light gray shales, white chalk, clay, scattered red shales.  
370- 600 Light gray shales and clay, scattered gumbo.  
600- 700 Light gray shales and clay.  
700- 760 Dark gray shales, light gray shales and clay.  
760- 800 Light gray shales, slightly calcareous gray shales.  
800- 900 Gray speckled chalk, gray shales and clay.  
900- 980 Gray shale, pieces of chalk.  
980-1090 Shales, gray and dark gray, pieces of crystalline limestone.  
1090-1190 Gray shale.  
1190-1250 Gray shale and gumbo.  
1250-1310 Crystalline limestone, calcite and shell spicules cemented, speckled black chalk.  
1310-1390 Dark gray shale, scattered speckled black chalk pieces.  
1390-1480 Shales, dark gray and gray.  
1480-1540 Shales, dark gray and gray, sandy shale.  
1540-1590 Shales, dark gray.  
1590-1730 Loose sand, dark gray shale.  
1730-1780 Loose sand, dark gray shale.  
1780-1840 Sandstone, loose sand, brown sandstone pellets, light and dark gray shales.  
1840-1860 Light and dark gray shales, loose sand, pyrite cemented sandstone.  
1860-1910 Sandstone, loose sand, light and dark gray shales.  
1910-2070 Shales, dark gray and light, scattered pieces of sandstone and loose sand.  
2070-2090 Sandstone, pyrite, cemented sandstone.  
2090-2120 Sandstone.  
2120-2200 Varicolored shales, maroon, yellow, brown, lavender, sandstones and loose sand.  
2200-2240 Rusty loose sand, plus small amounts of above.  
2240-2260 White massive limestone, pink and gray limestone  
2260-2270 Hard black shale.  
2270-2320 Gray limestone, trace of sandstone.  
2320-2340 Loose sand, trace varicolored shale.  
2340-2400 Varicolored shales, loose sand, trace of limestone.  
2400-2510 White to gray limestones.

2510-2600 Limestone, white, gray tan, granular, porous.  
2600-2640 Limestone, pieces of red and gray cal. shale.  
2640-2690 Oolitic limestone.  
2690-2760 Gray granular limestone, pieces of dark gray shale.  
2760-2830 Oolitic limestone, white and gray limestones.  
2830-2880 White limestones and scattered oolitic limestone.  
2880-2960 White limestones, granular limestones, dolomite at base.  
2960-3010 Loose sand, calcareous conglomerate, varicolored shales.  
3010-3050 Dark crystalline dolomite.  
3060-3360 Crystalline and porous dolomites.  
3360-3460 White limestone and dolomite.  
3460-3490 Pale green shale.  
3490-3560 Green soapy shale.  
3560-3580 Coarse sandstone, loose quartz.  
3580-3611 Gray granite.

# LOG

Carter Oil Company  
Stratigraphic Well #2  
Stanley County, South Dakota  
Sec. 12, T. 9 N., R. 27 E.  
Curb Elevation 1786'

- 0- 60 Loose sand.
- 60- 140 Loose sand, gray shale.
- 140- 350 Gray shale (Loose sand at 190-200).
- 350- 510 Gray shale, gray gumbo, some slightly calcareous shale.
- 510- 650 Gray shale, gray gumbo, black shale in upper part.
- 650- 780 Calcareous gray gumbo and gray shale.
- 780- 860 Speckled calcareous gray shale or chalk.
- 860- 990 Calcareous gray gumbo and gray shale.
- 990-1230 Gray shales scattered calcareous gray shale.
- 1230-1300 Gray shales, crystalline limestone, speckled chalk.
- 1300-1730 Gray shales, (pieces of coal at 1660-70).
- 1730-1810 Shales, gray, light gray (pieces of oil saturated sandstone at 1790-1800).
- 1810-2030 Sandstone pieces throughout, shales, gray, light gray, some calcareous.
- 2030-2080 Shales, gray.
- 2080-2130 Shales, gray, hard crystalline limestone. Pyrite cemented sandstone in upper part.
- 2130-2210 Shales, gray, red oxide pellets in upper part, brown clay in lower part.
- 2210-2290 White calcareous quartz sandstone, round loose quartz grains, pieces of pink limestone, gray shales. Varicolored shales in upper part.
- 2290-2310 Shales gray, pink limestone, few round loose quartz grains.
- 2310-2360 Sandstone white calcareous, gray shales, pieces of limestone.
- 2360-2390 Limestone, gray; limestone, oolitic, porous.
- 2390-2430 Anhydrite pieces, hard gray limestone, shales, gray black, scattered flints.
- 2490-2500 Loose quartz sand, gray limestone.
- 2500-2510 Shales, gray, black, pieces of limestone.
- 2510-2560 Hard gray limestone, shales, green, gray.
- 2560-2650 Shales, pale green, reddish brown, yellow, brown pieces of limestone throughout.
- 2650-2710 Shales, gray, light gray calcareous, black, anhydrite at 2700-10.
- 2710-2740 Various colored shales, black yellow green. Calcareous sandstone and loose quartz sand.
- 2740-2770 Gray limestone and some various colored shale, no red shales.
- 2770-2830 Limestone, gray and white; shales, gray, light gray pieces of various colored shales at base,

2890-2960 Limestone, oolitic fossiliferous.  
2960-3260 Limestone, gray, light gray, interbedded with  
gray shales.  
3260-3300 Loose sand, shales, gray green, red, calcareous  
conglomerate, light gray, white sandy chalk.  
3300-3350 Limestone, porous, gray crystalline, gray shales,  
white sandy chalk, conglomerate at base.  
3350-3450 Limestone and dolomite, shales, gray black, some  
sandy.  
3450-3590 Dolomite.  
3590-3780 Limestone gray shale at 3610-20 and 3740-50.  
3780-3800 Shales, green, gray, loose quartz grains, gray  
limestone.  
3800-3890 Shales, green, pieces of limestone throughout,  
loose sand at base.  
3890 Total depth.

LOG

U. S. Government  
Pierre Airport #1  
Hughes County, South Dakota  
Sec. 35, T. 111 N., R. 79 W.

- 0- 20 Soils, pebbles, gumbo.
- 20- 100 Gray shale and gumbo.
- 100- 230 Gray shale and brown gumbo.
- 230- 290 Hard gray shale.
- 290- 320 Hard gray shale, sandy calcareous gumbo.
- 320- 490 Shales, gray, some calcareous, calcareous gumbo, mica, bentonite at 20-30, black shale in lower part.
- 490- 560 Gray shale, gumbo, white clay.
- 560- 690 Chalk, light, speckled.
- 690- 850 Hard gray shales, some calcareous gray shales, dark gray shales.
- 850- 980 Gray shale, few pieces of chalk.
- 980-1010 Gray gumbo shale.
- 1010-1110 Gray shale, gray calcareous shale, pieces of dark crystalline limestone, calcareous gray gumbo.
- 1110-1170 Gray speckled calcareous shale and gumbo.
- 1170-1230 Gumbo, black, dark gray, some calcareous.
- 1230-1310 Gray splintery shale.
- 1310-1390 Gray shale, some dark gray to black.
- 1390-1510 Gray shale, brown sandstone, pieces of reddish brown shale.
- 1510-1550 Loose sand, gray shale.
- 1550-1670 Gray shale, bentonitic gumbo, some calcareous gray shales.
- 1670-1720 Gray shales, hard slightly calcareous gray shale, gumbo.
- 1720-1820 Pieces of sandstone, some calcareous gray shale, gumbo.
- 1820-1840 Loose sand, pieces sandstone, gray shale.
- 1840-1895 Loose sand, loose quartz, sandstone, rusty pieces of pyrite cemented sandstone at 1840-50 and 1850-95.
- 1895-1945 Sandstone, pyrite rust, loose sand at 1935-45.
- 1945-2115 Clays, maroon, buff, yellow, purple, lavender; few pieces of pyrite, cemented sandstone at 2065-2115.
- 2115-2125 Loose quartz; pieces of pyrite, cem. sandstone.
- 2125-2185 Limestone, black, gray, black shale at 2145-65.
- 2185-2215 Pyrite, limestone, black, gray loose quartz.
- 2215-2245 Shale, varicolored, loose quartz, sandstone.
- 2245-2295 Limestone pink, white, brown, oolitic at base.
- 2295-2325 Oolitic limestone, small amounts of varicolored shale, loose quartz.
- 2325-2365 Coarse sandstone, porous limestone, loose quartz, small amounts of varicolored shale.